Spatial heterogeneity of soil-derived CO_2 efflux in three tropical Australian savannas

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Introduction

•Soil-derived CO_2 efflux is one of the largest fluxes in the global C cycle and tropical savanna ecosystems are estimated to cover 20% of the land surface and account for up to 30% of Primary Production (Grace, 2004; Grace et al., 2006; Scurlock & Hall, 1998).

•These ecosystems are characterised by highly seasonal rainfall and consist of a mix of trees and grasses that leads to local heterogeneity in soil properties (Bird et al., 2000; Coetsee et al., 2010; Wang et al., 2009).

Methodology

•Soil-derived CO_2 efflux, and soil temperature was measured using a Licor-8100 portable infrared gas analyser and temperature probe. 49 measurements have been taken at each site on a monthly basis for 2 years with sampling locations stratified based on proximity to trees. Plot level soil moisture was measured using a ThetaProbe or Hydrosense II moisture probe.

•A generalised additive mixed model was fitted to the data using the `gamm()` function in R using time and distance to the nearest tree as independent variables.

Study sites

All three sites are *Eucalyptus* open woodland located on the Atherton tablelands in the wet-dry tropics of Queensland

Koombooloomba	Davies Creek	Brooklyn Station
Perennial grassy understorey with clayey soil on basalt	Perennial grassy understorey with sandy soil on granite	Annual grassy understorey on clayey alluvial soil
M.A.P. 2041 mm	M.A.P. 1178 mm	M.A.P. 917 mm



What are the sources of variation in soil-derived CO_2 efflux in terms of climate and tree/grass distribution?

Results & Discussion

•Fluxes were consistently higher at tree locations with measurements close to trees ~1.5-2 times greater than measurements remote from trees although this difference was prone to change according to season (see Figure 1). Measurements within 2m of a tree accounting for 30%, 28% and 21% of the total soil-derived CO_2 efflux at Koombooloomba, Davies Creek and Brooklyn Station respectively while measurements within 5m of a tree accounted for 79%, 90% and 76% respectively.

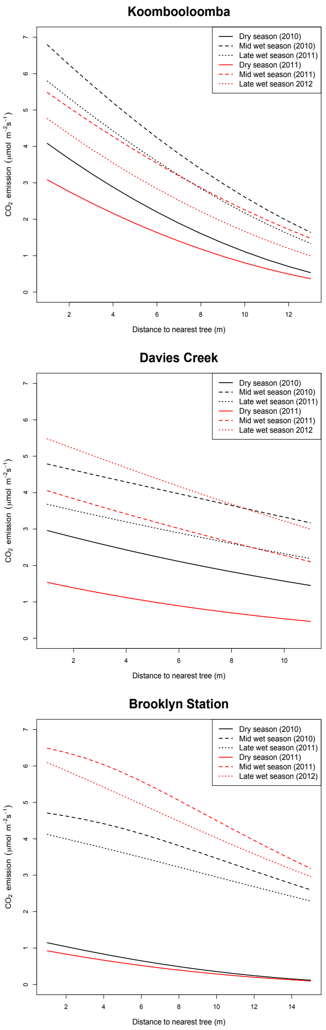

Figure 1: Modeled soil-derived CO_2 efflux by season in relation to distance from nearest tree for each site.

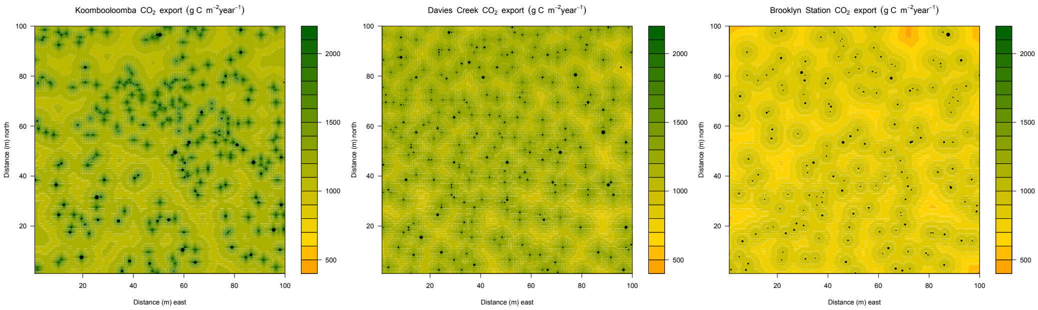

Figure 2: Modeled total CO_2 export for each site with relation to trees averaged over the study period

•Total C export was biased towards tree locations (see Figure 2). Total C export was 12.6, 11.2 and 8.0 Mg C ha^{-1} y^{-1} for the Koombooloomba, Davies Creek and Brooklyn Station sites respectively. Compared to previous studies in tropical savannas, this is lower than cerrado systems in Central Brazil (17.3 Mg C ha^{-1} y^{-1}; Butler et al., 2010), but similar to a grassland in the Republic of Congo (9.9 Mg C ha^{-1} y^{-1}; Caquet et al., 2012) and *Eucalyptus* woodlands in NT, Australia (8.1-17.5 Mg C ha^{-1} y^{-1}; Richards et al., 2012)

•Seasonal fluxes were influenced by both soil moisture and temperature (see Figure 3). The Brooklyn site was consistently either moisture limited or retarded during periods of inundation (indicated by circles on Figure 3) with similar constraints evident at the Davies Creek site. This is consistent with other arid/semi-arid systems (for example, Tang & Baldocchi, 2005; Williams et al., 2009) while the Koombooloomba site was influenced by both temperature and moisture, consistent with temperate systems and tropical rainforests (for example, Epron et al., 2006).

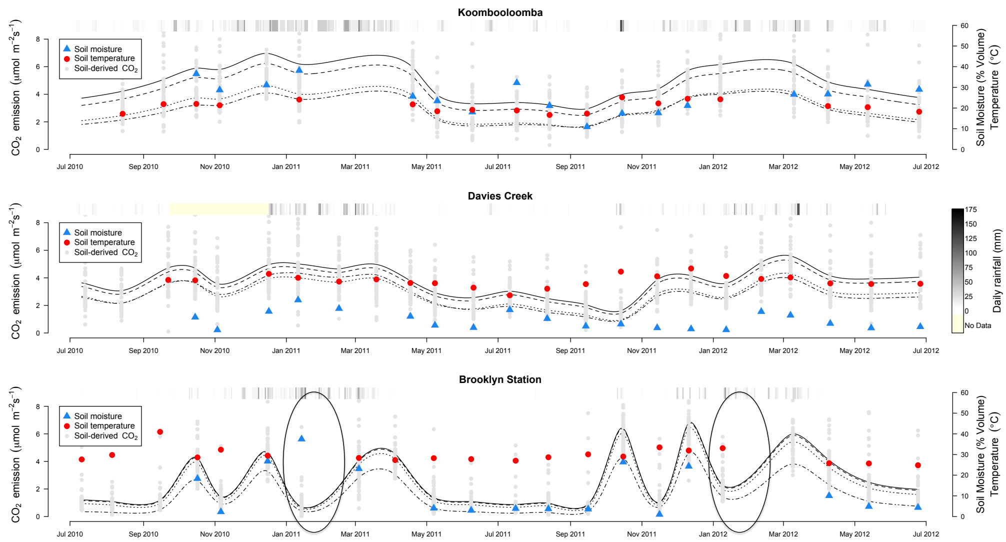

Figure 3: Modeled CO_2 fluxes at 0.5m (——), 1m (- -), 3m (----) and 10m (-·-) from the nearest tree for each site with measured CO_2 fluxes, daily rainfall, soil moisture and soil temperature. Periods of inundation at the Brooklyn site are circled.

Conclusion

•Savannas are dynamic and heterogeneous ecosystems, both spatially and temporally, and this is reflected in patterns of soil derived CO_2 efflux. Failure to account for both spatial and temporal variation can lead to significant misrepresentation of C losses from these systems and suggests that reasonably complex models may be required to accurately estimate C budgets.

•Seasonal patterns of soil-derived CO_2 efflux at these sites moderated by both temperature and soil moisture or by soil moisture alone, however results were confounded as periods of high temperature often coincide with periods of high moisture. Thus further research is required to elucidate the dynamics of these complex relationships.

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